

Improving small ruminant production in mixed crop-livestock systems through feed and health interventions in southern Mali



Technical Report

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Table of Contents

Table of Contents.....	1
Summary	2
1. Introduction.....	4
2. Methodology	5
2.1. Study area.....	5
2.2. Household selection for the study and animal management.....	6
2.3. Flock monitoring and data collection.....	8
2.4. Collection of feed and faecal samples	9
2.5. Laboratory analysis of feed and faecal samples	10
2.6. Statistical analysis.....	10
3. Results and Discussion.....	10
3.1. Flock structure and dynamic.....	10
3.2. Body weight development and change	15
3.3. Manure production and nutrient content	17
3.4. Nutritional quality of the available feed resources	21
3.5. Partial cost and benefit analysis.....	23
3.6. Feedback from the farmers about the pilot study.....	24
4. Conclusion and Recommendations	27
Acknowledgement	28
5. References	28

Summary

Small ruminants are an integral part of mixed crop and livestock systems in Mali and they fulfil various roles in household's food security as source of meat and milk, and means of additional income to meet food and cash needs. Besides, small ruminants also produce manure which is an invaluable source of organic matter for improving soil fertility. However, small ruminant production in Mali is challenged by the poor performance of animals largely due to inadequate nutrition and diseases. Given the low inputs into sheep and goats production by the smallholder farmers, their animals are rarely vaccinated or treated regularly against diseases and supplementary feeding is often on an ad hoc basis. Combining health and feed interventions can lead to a better animal performance than a single technology. Based on our experience and promising results from feed and health interventions for improved small ruminant production in Ghana under Africa RISING project, a pilot study was initiated in Mali involving combined feed and health interventions in two communities namely Sirakele and Zanzoni in Koutiala district in the southern region of Mali. The objective of this study was to assess the effects of combined feed and health interventions on small ruminant production in mixed crop and livestock systems in southern Mali. Zanzoni village served as control while Sirakele received feed and health intervention. Twenty households were randomly selected in each community for 1 yearlong study spanning the period August 2016 to August 2017. Results from the study showed that the average household flock size for sheep and goats in the feed and intervention group doubled within a year (August 2016 – Sheep: 5.30 ± 0.81 ; Goats: 6.75 ± 1.24 ; July 2017 - Sheep: 11.90 ± 1.56 ; Goat: 12.70 ± 2.04) whereas average flock size in control group (Zanzoni) remained largely the same within the same period. The average number of birth per household were 5.72 ± 2.10 and 15.20 ± 3.41 for control and treatment groups, respectively. The mortality rate was significantly lower in Sirakele with the intervention than in the control site. Results on weight development showed that the goats and sheep under treatment gained 42.98 ± 3.28 and 47.12 ± 2.73 g/day, respectively compared to 22.59 ± 2.29 and 16.58 ± 2.74 g/day for goats and sheep, respectively under control. Significantly more manure was collected from the animals under the feed and health intervention compared to those in the control. Partial cost benefit analysis showed the annual net return of $107,260 \pm 25,388$ FCFA

per household for the feed and health intervention in Sirakele compared to 89,798±8,693 FCFA per household for the control group in Zanzoni. The results confirm that feed and health intervention lead to significant improvement in small ruminant production in a profitable manner.

1. Introduction

Small ruminants are an integral part of mixed crop and livestock systems in Mali and they fulfil various roles in household's food security as source of meat and milk, and means of additional income to meet food and cash needs (Wilson, 1986; Ba et al., 1996). In West African Sahel, the majority of farmers raise small ruminants for immediate source of income, as insurance against emergencies and as mitigating measures in case of crop failures (Wilson, 1991). Besides, small ruminants also produce manure which is an invaluable source of organic matter for improving soil fertility. In Mali, about 90% of the households own sheep and goats as they are important for the livelihood strategies of many resource poor rural households (Ba et al., 1996). Small ruminant rearing provides employment opportunities for rural women and youth as they are heavily involved in the management of sheep and goats (Wilson, 1991; Lebbie, 2004). The short generation intervals of small ruminants compared to cattle allows for rapid flock growth within a short provided there are adequate nutrition and veterinary care. Compared to cattle, small ruminants tend to withstand drought much better (Lebbie, 2004). For example, Wilson (1991) reported that the during the drought of the early 1980s in the Sahel, cattle losses were over 80% while those of small ruminants were not more than 50% of the flocks.

In view of the potential for rapid flock growth and the varied function small ruminants fulfil in mixed crop and livestock systems, they could be a means of improving household food security and poverty alleviation among the smallholder farmers. However, small ruminant production in Mali is challenged by the poor performance of animals largely due to inadequate nutrition and diseases (Wilson, 1986; Ba et al., 1996). Given the low inputs into sheep and goats production by the smallholder farmers, their animals are rarely vaccinated or treated regularly against diseases (Ba et al., 1996) and supplementary feeding is often on an ad hoc basis (Ayantunde et al., 2014). Consequently, high mortality rate is common in small ruminant flocks in Mali (Ba et al., 1996) as well as in other Sahelian countries. One way mortality could be reduced is by vaccinating small ruminants against main diseases such as Pasteurellosis and Peste des Petits Ruminants (PPR), and deworming them. In addition to healthcare, strategic supplementation of the small ruminants is also essential to improve their performance (Ben Salem and Smith, 2008; Nantoume et al., 2011; Konlan et al., 2017). Combining health and feed

interventions will lead to a better animal performance than a single technology. Based on our experience and promising results from feed and health interventions for improved small ruminant production in Ghana under Africa RISING project (Avornyo et al., 2015; Konlan et al., 2017), a pilot study was initiated in Mali involving combined feed and health interventions in two Africa RISING intervention communities in Koutiala district in the southern region of Mali.

The underlying hypothesis for this study is that combinations of improved management practices will result in higher animal productivity, income, and household food security than single technologies. In this study, the interventions focus mainly on provision of healthcare and supplementary feeding. The objective of the study was to assess the effects of combined feed and health interventions on small ruminant production in mixed crop and livestock systems in southern Mali. The specific objectives were: (1). To assess the effects of feed and health package on sheep and goats live weight changes, flock dynamics (birth, death, offtake) and manure production. (2). To quantify the costs and benefits of feed and health package in smallholder small ruminant production.

2. Methodology

2.1. Study sites

The study was undertaken in Sirakélé (-5.48° long; 12.51° lat) and Zanzoni (-5.57° long; 12.61° lat) villages in Koutiala district in southern region of Mali. Sirakélé is a village in the rural commune of Songoua and situated about 15 km north of Koutiala, while Zanzoni is located in commune Fakolo about 35 km of Koutiala. Koutiala district is the cotton production capital of Mali. Both study communities are in a region with a high concentration of smallholder crop and livestock farmers which implies that mixed crop and livestock system is the dominant farming system. The two study sites have a Sudanian climate characterized by an alternation of dry, and rainy season that last about six months each. The dry season is normally between November and April while the rainy season is between May and October. Annual precipitation varies between 750 - 1100 mm. Crop farming and livestock husbandry are the main sources of household foods and income in the study areas. The feed resources in both study sites are

similar as reported by Umutoni et al. (2015) from the study on the evaluation of feed resources in Koutiala and Bougoni districts in southern Mali. The main feed resources are natural pastures, crop residues and agro-industrial by-products. The present report was based on one year monitoring of sheep and goat flocks belonging to 40 households in two communities between August 2016 and August 2017.

2.2. Household selection for the study and animal management

The study involved 20 households in each community. The households were selected randomly based on ownership of sheep and or goats, and willingness to participate in the study which entails monitoring of their animals for about 1 year. Both communities are among the Africa RISING project intervention sites. The project intervention communities are in the “Zones of Influence” of United States Agency for International Development (USAID) Program in Mali, the donor for Africa RISING project under the U.S. government’s Feed the Future Initiative. The overall goal of the project is to create opportunities for smallholder farm households to move out of hunger and poverty through sustainably intensified farming systems that improve food, nutrition, and income security, particularly for women and children, and conserve or enhance the natural resource base. At the beginning of the study in August 2016, the two communities were randomly allocated to either control or treatment group. The control group consists of the 20 selected households in Zanzoni village while the treatment group comprises of the 20 selected households in Sirakele.

The sheep and goat flocks in the treatment group received vaccination against Pasteurellosis, PPR and trypanosomiasis, deworming and regular health care in case of any sickness, and supplementary feed (300 g of cotton seed cake per animal per day) throughout the 12 months of the study. Cotton seed cake was used as supplement in this study as it is readily available in the study sites due to widespread cultivation of cotton. The quantity of cotton seed cake offered was based on similar studies in Ghana where between 200 and 300 g of supplement was offered per animal (Konlan et al., 2017). Given that experiment was undertaken on farm, physiological status was not considered while deciding the amount of supplement to be distributed to animals as it is difficult to adjust quantity offered to animal physiological status under the rural farmer’ conditions. The treatment package is referred to as

“Feed-health (FH) intervention” in this report. Vaccines produced by the Malian Central Veterinary Laboratory (Laboratoire Central Vétérinaire de Bamako) named “Ovipeste” and “Pastovin” were used for vaccination against PPR and Pasteurellosis, respectively. Sheep and goats under FH intervention were vaccinated once per year against PPR at the dosage of 1 ml per animal and twice per year against Pasteurellosis at the dosage of 2 ml per animal. The treatment animals were also vaccinated against trypanosomiasis with Verben B12 and Kelamidum. Prophylaxis in the form of antibiotic and multivitamin injections, and deworming were given to treatment animals. Deworming was done twice in a year, at the beginning of the study in August and at the end of the rainy season in October using SYNANTHIC (oxfendazole). Treatment animals were also provided with the curative treatment when necessary.

The flocks in the control group did not receive any feed and or health intervention from the project. However, it has been mentioned that farmers in the control group did treat their sick animals though irregularly and did offer crop residues particularly sorghum straw, cotton straw and groundnut haulms after the crop harvest, and browses in the late dry season on an ad hoc basis. In both study sites, daily management of sheep and goats involved grazing of natural pastures during the rainy season and crop residues in the dry season by most of the animals. Animals that were being fattened, lactating does and ewes, and sick animals were normally left behind around the homesteads, and were fed. The young animals (lambs and kids) were not allowed to graze until they were 3 to 4 months of age. On returning from grazing, the animals in FH intervention were each offered cotton seed cake as supplement, which was often consumed immediately. At night, the animals in both control and treatments groups were tethered to pickets or penned in enclosures or shelters around the homesteads. About 94% of the sheep breed in the study areas was Djallonke with the remaining belonging to Sahelian long legged breeds. The Sahelian long legged sheep were mainly male for fattening. The goat breed was also dominated by West African dwarf (about 96%) with few Sahelian long legged breed.



Picture 1. Rams being fattened tethered at the homestead.

2.3. Flock monitoring and data collection

All the sheep and goats in the selected 20 households each in Zanzoni (control) and Sirakele (feed-health intervention) were ear-tagged at the beginning of the study in August 2016 for identification and were weighed (see the Picture 2 of animal weighing). At the beginning of the study, the total flock of the 20 households consisted of 78 sheep and 84 goats in Zanzoni making a total of 162 animals while in Sirakele the total flock consisted of 106 sheep and 135 goats making 241 animals in total. All animals in both control and treatment groups were weighed every month for 3 days consecutively. The two field technicians responsible for the monitoring of the experimental animals visited each household every month to collect data of any change in the household flock (demographic event) including birth, death, sale, animal slaughtered, giving out animal as gift or on caretaking, receipt of animal as gift or on caretaking arrangement, and loss through theft. The data on occurrence of death in the flocks was used to calculate mortality rate which is the number of death recorded as a percentage of the total flock at the beginning of the study. Offtake rate was calculated as the number of animal sold, slaughtered and given out as a percentage of the total flock at the beginning of the study. The manure deposited at the enclosures or shelters by the animals were collected each morning

after removal of the sheep and goats from the pens by each household in both control and treatment groups, air dried and stored in a bag for weighing every month by the AMEDD field technicians.



Picture 2. Animal weighing

2.4. Collection of feed and faecal samples

Two samples of feed resources fed to the experimental animals were collected in the early and late dry seasons. The feed resources were mainly crop residues, browses and agro-industrial by-products. In total, 46 feed samples were collected and ground to pass through 2mm sieve for laboratory analysis of their chemical composition. Two faecal (manure) samples of 0.5 kg fresh weight were collected monthly from each household and these were air dried. Collected samples for each household were combined per season (wet/rainy, early dry and late dry) and

ground for laboratory analysis. In total 120 faecal samples were prepared for the laboratory analysis.

2.5. Laboratory analysis of feed and faecal samples

Samples of feed resources in the study sites were collected mainly in the early and late dry seasons (October 2016 to May 2017) and were air dried and prepared for laboratory analyses. Samples of feeds collected were analyzed for dry matter (DM), ash content, nitrogen, fiber components [neutral detergent fiber (NDF), acid detergent fiber (ADF), and acid detergent lignin (ADL)] and *in vitro* organic matter digestibility (IVOMD) using near infrared reflectance spectroscopy (NIRS) technique. The sample fineness for NIRS analysis was 2mm. The wave length range to estimate the chemical composition was 1100 to 2500 nanometer. NIRS is an indirect analytical method based on the development of empirical models in which the concentration of a feed constituent is predicted from complex spectral data (De Boever et al., 1995). Crude protein was estimated from nitrogen content (nitrogen x 6.25). Metabolizable energy (Mcal/kg DM) was derived from IVOMD. The faecal samples were analysed for DM, OM, N and phosphorus (P) concentration.

2.6. Statistical analysis

Data analysis was performed with SAS (SAS, 1987) using Means procedures for descriptive statics while T-Test was used to compare the means of demographic events (birth rate, mortality rate, offtake rate etc.), average daily gains, quantity of manure collected per household and cost and benefit between the control group and the group with feed-health intervention. Unless otherwise specified, the level of significance was set at $P < 0.05$.

3. Results and Discussion

3.1. Flock structure and dynamic

The average flock size per household at the beginning of the study in August 2016 for sheep was 3.90 ± 0.82 and 5.30 ± 0.81 for the control and feed-health intervention groups, respectively (Table 1). For goats, the average flock size was 4.20 ± 0.97 and 6.75 ± 1.24 for the control and FH intervention groups, respectively. The results showed that the both sheep and goat flocks were dominated by female irrespective of the treatment. At least 80% of the sheep flock was female at the beginning of the study while at least 75% of the goat flock was female at the same period. These results agreed with the results on small ruminant production in the agro-pastoral systems in Central Mali by Wilson (1986) where it was reported that the female accounted for at least 75% of the sheep and goat flocks. Generally, the flock is dominated by female animals for reproduction and for flock growth, whereas the male sheep and goats are often sold to meet household cash needs as reported by Ba et al. (1996) that the offtake rate of male animals is often high compared to the female animals. The average flock size per household of sheep and goats at the beginning of the study was lower than for the agro-pastoral sheep and goat flock in Central Mali reported by Wilson (1986) which were on average 9.48 and 23.57 for sheep and goats, respectively. The higher flock size of agro-pastoral flock than those of mixed crop-livestock farmers in southern Mali is expected as the farmers in southern Mali are more oriented towards cropping than raising livestock whereas the agro-pastoralists are livestock keepers by tradition though they have settled down to grow crop (Ayantunde et al., 2011).

After a year, the flock size of the control group remained largely the same as at the beginning of the study (Sheep - Male 0.65 ± 0.22 ; Female: 2.95 ± 0.73 ; Goat - Male: 1.15 ± 0.33 ; Female: 3.45 ± 0.72) whereas the flock size of sheep and goats per household under FH intervention doubled within the same period (Table 1). The total number of the flock for the FH group increased from 106 sheep at the beginning of the study (August 2016) to 236 at the end of July 2017 while the number of goats increased from 135 to 252 (Figure 1). These results demonstrate that feed and health interventions led to significant increase in flock size of sheep and goats within a short period through better reproductive and growth performance. Similar results were reported by Ba et al. (1996) in Mali with introduction of health treatment alone. Konlan et al. (2017) also reported synergistic benefits of the combined effect of providing concentrate feed and healthcare to small ruminants kept by smallholder farmers in Northern

Ghana. Similar trend of significant increase in small ruminant number with feed and health intervention was reported by Avornyo et al. (2015) also in Northern Ghana.

Table 1: Household flock composition (mean \pm standard error) at the beginning (August 2016) and at the end of the study (July 2017) in Zanzoni (control) and Sirakele (Feed-health intervention) in Koutiala district

Variable	Control (n=20)	Feed-health (n=20)
Beginning of the study (August 2016)		
Sheep		
Average number of male	0.75 \pm 0.33 ^a	1.10 \pm 0.25 ^a
Average number of female	3.15 \pm 0.69 ^a	4.20 \pm 0.70 ^a
Average total flock	3.90 \pm 0.82 ^a	5.30 \pm 0.81 ^a
Goat		
Average number of male	0.50 \pm 0.20 ^a	1.60 \pm 0.42 ^b
Average number of female	3.70 \pm 0.81 ^a	5.15 \pm 0.97 ^a
Average total flock	4.20 \pm 0.97 ^a	6.75 \pm 1.24 ^a
End of the study (July 2017)		
Sheep		
Average number of male	0.65 \pm 0.22 ^a	5.20 \pm 0.93 ^b
Average number of female	2.95 \pm 0.73 ^a	6.70 \pm 0.93 ^b
Average total flock	3.60 \pm 0.84 ^a	11.90 \pm 1.56 ^b
Goat		
Average number of male	1.15 \pm 0.33 ^a	3.90 \pm 0.89 ^b
Average number of female	3.45 \pm 0.72 ^a	8.80 \pm 1.35 ^b
Average total flock	4.60 \pm 0.99 ^a	12.70 \pm 2.04 ^b

Values for each variable with different superscript are statistically significant ($P < 0.05$).

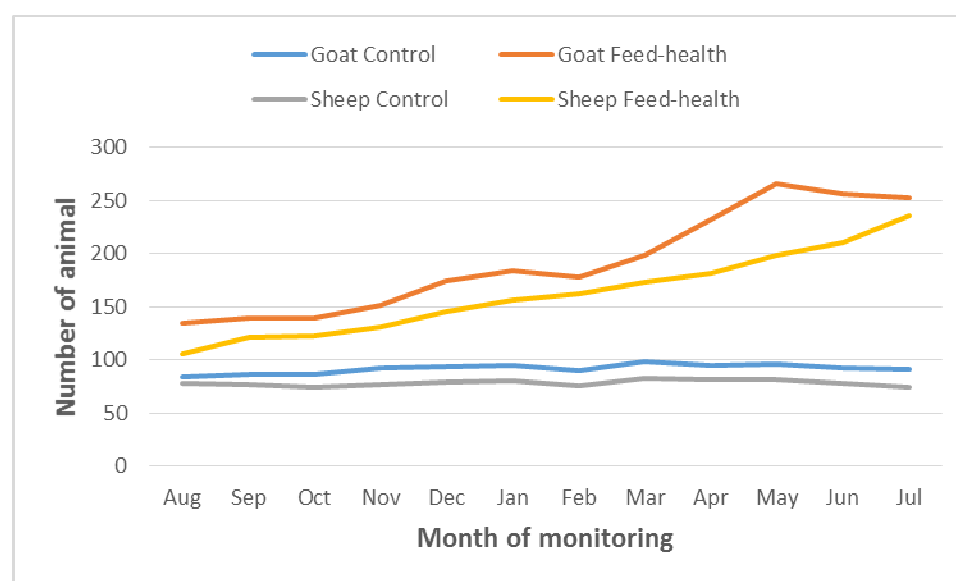


Figure 1: Flock growth of households under control and feed-health intervention in Zanzoni and Sirakele, respectively in Koutiala district during one year of monitoring.

Results on flock dynamic (Table 2) showed significant differences in birth rate, mortality rate and offtake rate between the control and feed-health intervention group. The mortality rate of the control group was 30.4% during one year of the study while that of the FH group was 13.3%, which was significantly lower than for the control group. The results confirmed that mortality rate is always high in a small ruminant flock without adequate healthcare and nutrition (Konlan et al., 2017). According to Wilson (1986), the mortality rate can be up to 30% in sheep and goat flock in extensive livestock systems where healthcare is inadequate and nutrition can be poor, particularly in the dry season. Ejlersen et al. (2012) reported mortality rates of 25 to 32% for sheep flock and of 13 to 23% for goat flock in southern Mali based on recall survey. The major causes of death in the flocks in our study were diseases such as respiratory problem, diarrhea and fever, losses due to predator and injuries. Similar causes of death were reported by Ba et al. (1996) for small ruminant flock in semi-arid area of Mali. The results on repartition of birth and death in the control and FH groups between September 2016 and August 2017 are presented in Figure 2 and Figure 3. Most births tended to occur between March and September (Figure 2) while deaths tended to occur throughout the year though the lowest recorded cases of death were in January and February.

Table 2: Flock dynamic of sheep and goats under control (Zanzoni village) and feed-health intervention (Sirakele village) between August 2016 and August 2017

Variable	Control (n=20)	Feed-health (n=20)
Average number of birth per household	5.72±2.10 ^a	15.20±3.41 ^b
Birth rate (%)	69.9±3.4 ^a	126.7±4.9 ^b
Mortality rate (%)	30.4±2.7 ^a	13.3±3.1 ^b
Offtake rate (%)	30.4±2.9 ^a	38.8±3.1 ^b
Average price per animal sold (FCFA)	19,777±841 ^a	24,887±964 ^b
Average income from animal sale per household (FCFA)	38,537±7,560 ^a	169,125±26,545 ^b
Average number of animal purchased per household	0.02±0.01 ^a	0.34±0.04 ^a
Average number of animal slaughtered for consumption per household	0.04±0.02 ^a	0.09±0.02 ^a
Average number of animal given out as gift/caretaking per household	0.04±0.01 ^a	0.03±0.01 ^a
Average number of animal received for caretaking per household	0.01±0.01 ^a	0.08±0.03 ^a
Average number of animal lost to theft per household	0.03±0.01 ^a	0.04±0.02 ^a

Initial animal number was 241 sheep and goats in Sirakele, and 162 sheep and goats in Zanzoni

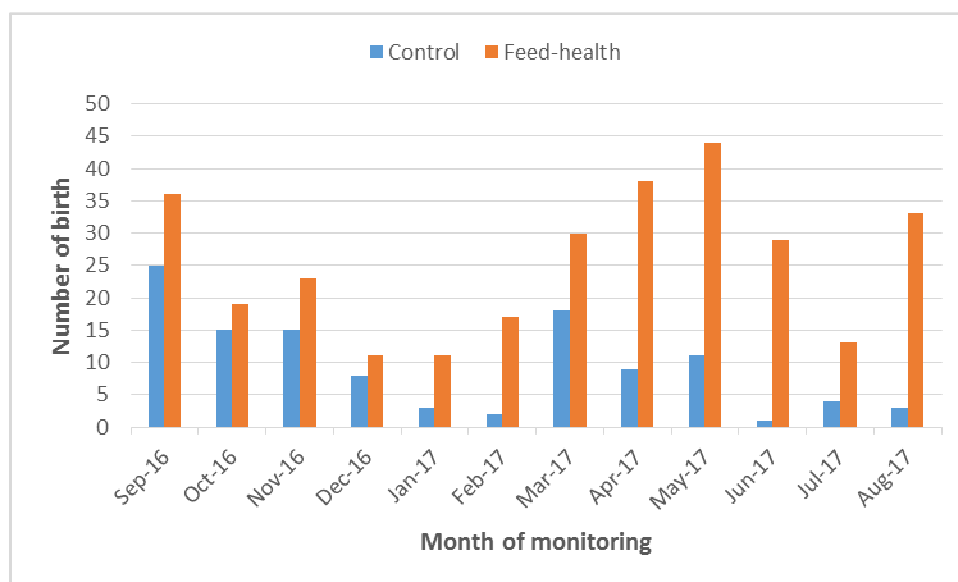


Figure 2: Number of birth in household flock under control and feed-health intervention in Zanzoni and Sirakele, respectively in Koutiala district.

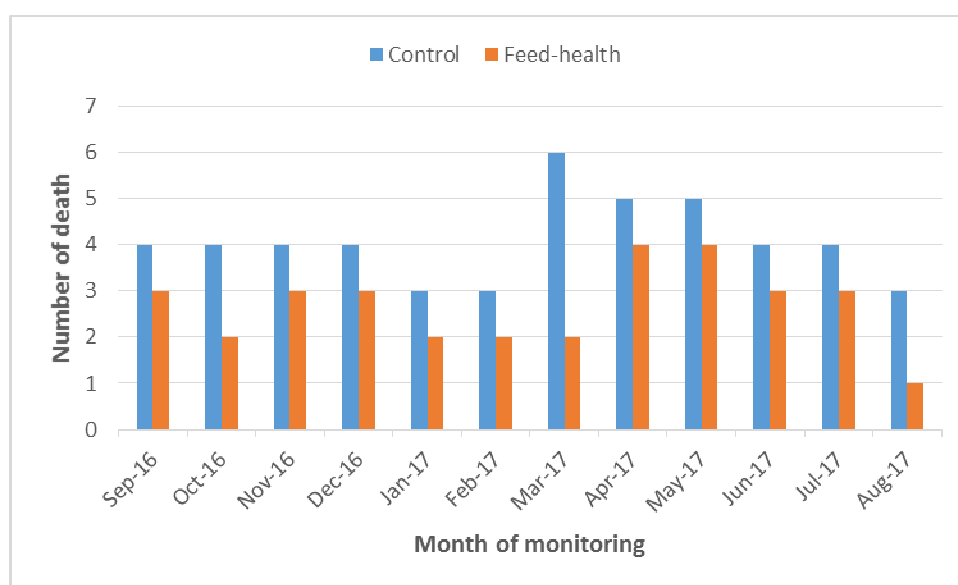


Figure 3: Number of death in household flock under control and feed-health intervention in Zanzoni and Sirakele, respectively in Koutiala district.

The annual offtake rates for sheep and goat flocks found in our study are similar to those reported by Ejlersen et al. (2012) of around 29.5% in southern Mali. Lower offtake rates of 19 to 26% were reported by Wilson (1986) for small ruminants in agro-pastoral systems in Central Mali. Offtake generally tended to be much higher in males than in females as the major reason for offtake is sale to meet immediate cash needs of the households and the males are

often targeted for this (Ba et al., 1996). In our study, we did not collect sex disaggregated data for the offtake but the anecdotal evidence from the participating households support the claim that offtake is higher in males than in females. Generally, offtake is influenced by the number of animals available, immediate cash needs, prevailing market prices and animal's age and condition. Interventions that lead to significant increase in flock size like supplementary feeding and healthcare will tend to increase offtake as shown by the significant difference between the offtake rate of the control group and the feed-health group in our study. In Mali and other West Africa Sahelian countries, sale of small ruminants is on one of the key strategies in coping with crop failures (Lebbie, 2004).

3.2. Body weight development and change

The results of this study showed that feed and health intervention had significant effect on body weight development and average daily gain (ADG) of sheep and goats (Table 3). The average daily gains of sheep and goats under control were 16.58 ± 2.74 and 22.59 ± 2.29 g/day while ADG for the animals that received feed and health intervention was almost double (Sheep: 47.12 ± 2.73 ; Goat: 42.98 ± 3.28). For few lambs and kids that were weighed at birth, the birth weights were similar for both control and treatment groups.

Table 3: Weight changes of goats and sheep over 1 year period under control and feed-health intervention in Zanzoni and Sirakele, Koutiala district

Variable	Control		Feed-health	
Goats				
	n	Mean ± se	n	Mean ± se
Weight at birth (kg)	2	1.50±0.0 ^a	5	1.20±0.12 ^a
Weight at 1 month (kg)	10	2.45±0.16 ^a	36	2.62±0.09 ^a
Weight at 3 months (kg)	36	5.65±0.17 ^a	101	5.71±0.13 ^a
Weight at 1 year (kg)	14	12.89±0.80 ^a	36	16.78±0.34 ^b
Average daily gain (g/day)	131	22.59±2.29 ^a	311	42.98±3.28 ^b
Sheep				
	n	Mean ± se	n	Mean ± se
Weight at birth (kg)	1	1.50±0.0	0	-
Weight at 1 month (kg)	6	2.92±0.27 ^a	10	3.00±0.13 ^a
Weight at 3 months (kg)	15	7.23±0.39 ^a	34	6.75±0.22 ^a
Weight at 1 year (kg)	3	18.5±0.76 ^a	17	22.34±0.88 ^b
Average daily gain (g/day)	117	16.58±2.74 ^a	225	47.12±2.73 ^b

Values for each variable with different superscript are statistically significant ($P < 0.05$).

The body weight development trend was similar up till the fourth month for sheep (Figure 4a) and up till the fifth month for goats (Figure 4b) under both control and treatment groups. Afterward, there was significant difference in the weight development of both groups. At one year of age, sheep and goats under FH group weighed significantly higher than those under control (Table 3).

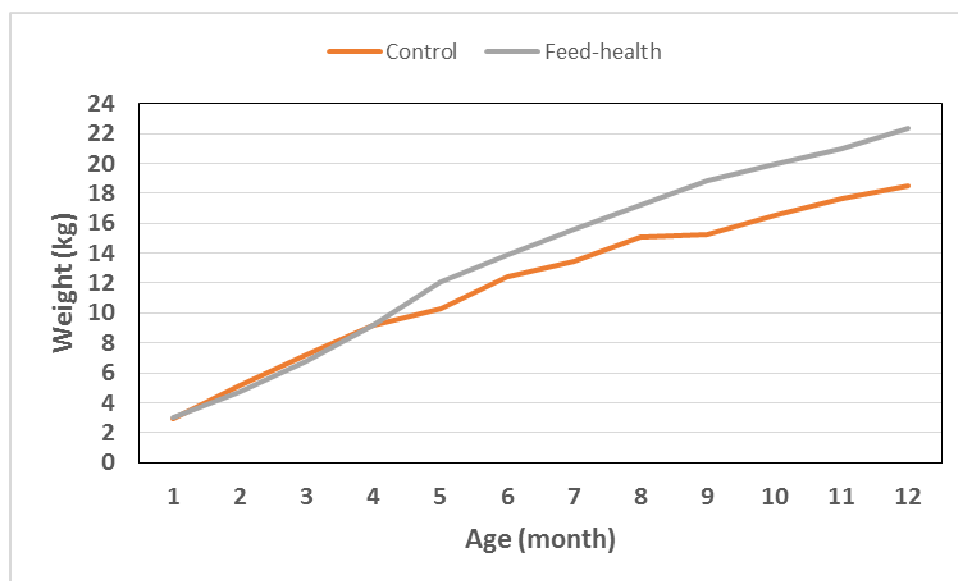


Figure 4a: Weight development of sheep under control and feed-health intervention from 1 to 12 months in Zanzoni and Sirakele, Koutiala district.

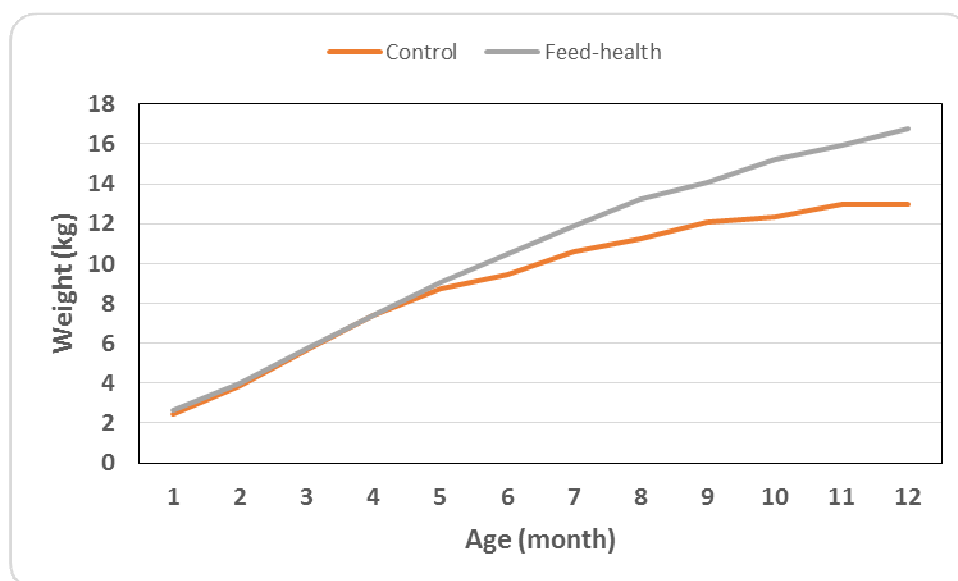


Figure 4b: Weight development of goats under control and feed-health intervention from 1 to 12 months in Zanzoni and Sirakele, Koutiala district.

The ADG values for sheep and goats for control and treatment groups were similar to those reported by Avornyo et al. (2015) for sheep and goats, and by Konlan et al. (2017) for sheep in studies that involved feed supplementation and provision of healthcare. Konlan et al. (2017) reported ADG of 17.8 and 45.4 g/day for sheep under control and healthcare, respectively. The average daily gain values for the treatment animals were approximately the same as the 48.98 g/day and 49.19 g/day reported by Obese (1998) and Issaka (2006) from feeding trials where Djallonke sheep were supplemented with groundnut haulms, and cotton seed and cowpea vines, respectively. The live weights of sheep and goat at 3 months and 12 months in this study were lower than those reported by Wilson (1986) of 7 kg for goat and 9 kg for sheep at 3 months, and 18 kg for goat and 24 kg for sheep at 12 months of age. This could be attributed to differences in breed as the sheep and goat breeds in agro-pastoral systems in Central Mali are mainly Sahelian long legged sheep and goat breeds and are heavier than the West Africa dwarf breeds which are dominant in southern Mali where our study was conducted. The higher body weight of sheep and goats as from 4 months of age showed that the effect of supplementary feeding and healthcare on body weight development is cumulative.

3.3. Manure production and nutrient content

Results of manure collected from sheep and goats by households under control and feed-health intervention are presented in Table 4. More manure were collected by the households that received feed-health intervention than those under control across all seasons (early dry, late dry and wet seasons). This suggests that feed and health intervention is also beneficial for soil fertility improvement as the farmers could collect more manure to apply to their crop fields. The main challenge of manure collected at homesteads is transportation to the crop field, particularly if it is far from the village. The manure collected per animal per day was highest for both groups (Control: 102 ± 4.06 g DM/animal/day; Feed-health: 121.52 ± 4.52 g DM/animal/day) in the late dry season while it was lowest in the wet season. This could be attributed to longer time spent around the homestead by the animals in the late dry season as there was virtually no feed in the grazing areas at this period which allowed for more manure to be collected. In the wet season, it is generally more difficult to collect manure as the water content in faeces is high. The quantities of manure collected from animals in both groups when expressed in g DM/

kg liveweight / day (Table 4) were much lower than the quantities of 10 to 13 g DM/kg liveweight/day reported by Ayantunde et al. (2007) for sheep under feeding trials using faecal collection bags. This shows that there were losses in the collection of the manure by the farmers in this study. Besides, the manure deposited by the animals during grazing could not be collected by the farmers which also explains the lower quantities of the collected manure in this study. Manure nitrogen and phosphorus contents were similar for both control and treatment groups except in the wet season when the nitrogen content was higher for the feed-health group than the control.

Table 4. Collected manure by households under control and feed-health intervention from experimental sheep and goats between September 2016 and August 2017 in Zanzoni and Sirakele, Koutiala district

Variable	Control	Feed-health
<i>Early dry season (Oct – Jan)</i>		
Collected manure – g DM/day/household	815±46 ^a	1729±65 ^b
Collected manure – g DM/animal/day	96.12±3.78 ^a	119.72±4.55 ^b
Collected manure – g DM/day/animal/kg live weight	5.14±0.19 ^a	5.88±0.24 ^a
Nitrogen concentration (g/kg DM)	20.95±0.31 ^a	21.35±0.29 ^a
Phosphorus concentration (g/kg DM)	3.76±0.13 ^a	4.96±0.14 ^b
Manure nitrogen output (g/day)	16.48±0.81 ^a	37.03±1.47 ^b
Manure phosphorus output (g/day)	2.81±0.14 ^a	8.64±0.43 ^b
Manure nitrogen output (g/animal/day)	1.98±0.07 ^a	2.57±0.10 ^a
Manure phosphorus output (g/animal/day)	0.35±0.02 ^a	0.60±0.03 ^a
<i>Late dry season (Feb – May)</i>		
Collected manure – g DM/day/household	891±49 ^a	2392±104 ^b
Collected manure – g DM/animal/day	102±4.06 ^a	121.52±4.52 ^b
Collected manure – g DM/day/animal/kg live weight	5.67±0.20 ^a	5.68±0.21 ^a
Nitrogen concentration (g/kg DM)	21.15±0.39 ^a	20.89±0.34 ^a
Phosphorus concentration (g/kg DM)	3.89±0.15 ^a	3.74±0.19 ^a
Manure nitrogen output (g/day)	18.74±1.04 ^a	50.51±2.60 ^b
Manure phosphorus output (g/day)	3.29±0.20 ^a	9.04±0.64 ^b
Manure nitrogen output (g/animal/day)	2.14±0.09 ^a	2.52±0.10 ^a
Manure phosphorus output (g/animal/day)	0.38±0.02 ^a	0.45±0.03 ^a
<i>Wet season (June – Sept)</i>		
Collected manure – g DM/day/household	774±41 ^a	2234±104 ^b
Collected manure – g DM/animal/day	95.54±4.27 ^a	112.27±4.64 ^b
Collected manure – g DM/day/animal/kg live weight	5.29±0.24 ^a	5.62±0.24 ^a
Nitrogen concentration (g/kg DM)	18.83±0.36 ^a	22.73±0.49 ^b
Phosphorus concentration (g/kg DM)	7.21±0.15 ^a	6.73±0.11 ^a
Manure nitrogen output (g/day)	14.53±0.81 ^a	51.30±2.78 ^b
Manure phosphorus output (g/day)	5.54±0.32 ^a	15.31±0.82 ^b
Manure nitrogen output (g/animal/day)	1.78±0.09 ^a	2.52±0.11 ^a
Manure phosphorus output (g/animal/day)	0.69±0.04 ^a	0.75±0.03 ^a

Values for each variable with different superscript are statistically significant ($P < 0.05$).

The values of nitrogen and phosphorus concentration in the manure found in this study were much higher than those reported by Ayantunde et al. (2007) from feeding trials with sheep fed with groundnut haulms as supplement in the early dry season in Niger. In their study, the nitrogen concentration ranged from 10.7 to 12.8 g/kg DM and the phosphorus concentration ranged from 1.9 to 2.8 g/kg DM. The higher values could be partly attributed to better quality feed in southern Mali than the millet straw as basal feed and groundnut haulms as supplement used in the feeding trials by Ayantunde et al. (2007) as high nutrient feed will generally result in higher nutrient content of the manure (Ayantunde et al., 2018). In addition, the higher values obtained in this study could be attributed to contamination as manure collected might have been contaminated by urine, feedstuffs offered to the animals and dusts. Given that manure collected by the households for application to the crop field is often a mixture of faeces and urine, our results give an indication of nutrients that may return to the soil. Higher manure nitrogen and phosphorus outputs were observed for manure collected by the households under the feed-health intervention than those in the control group which again confirms that better nutrition results in better manure quality.

The results on repartition of manure collected per household flock and per animal are presented in Figure 5 and Figure 6. The results showed that the quantity of manure collected per household per day tended to increase linearly from September 2016 to August 2017 for feed-health group while it remained almost the same for the households in the control group (Figure 5). When expressed as quantity collected per animal per day, the quantity collected was between 100 and 120 g DM/animal/day for the feed-health group while the values for the control group were between 80 and 100 g DM/animal/day (Figure 6). In view of the importance of animal manure for soil fertility in West African Sahel, the more manure that could be collected, the better for the smallholder farmers as manuring leads to increased crop yield (Ayantunde et al., 2018). The challenge to manuring is always insufficient number of animals.

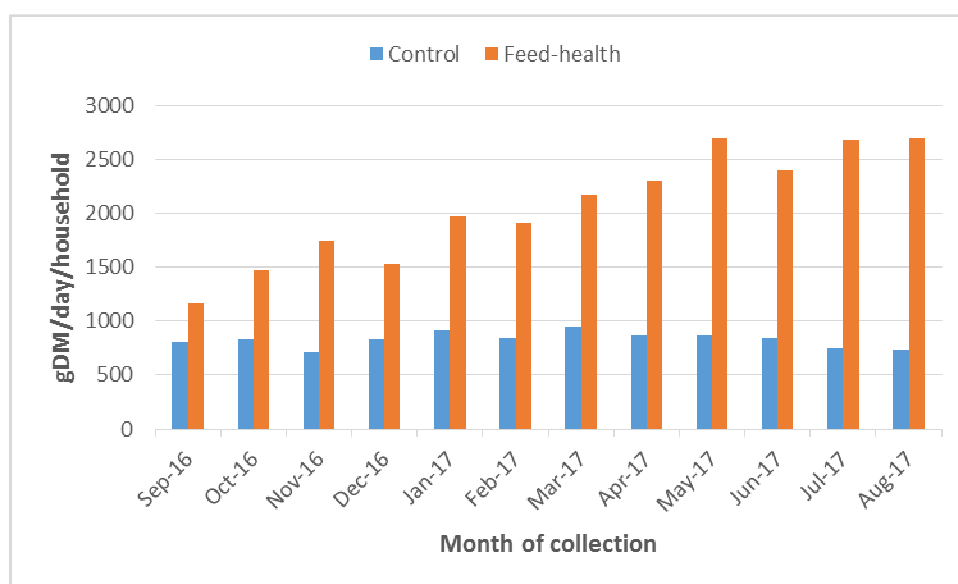


Figure 5: Manure collected per day per household (g DM/day/household) by farmers from sheep and goats under control and feed-health intervention groups

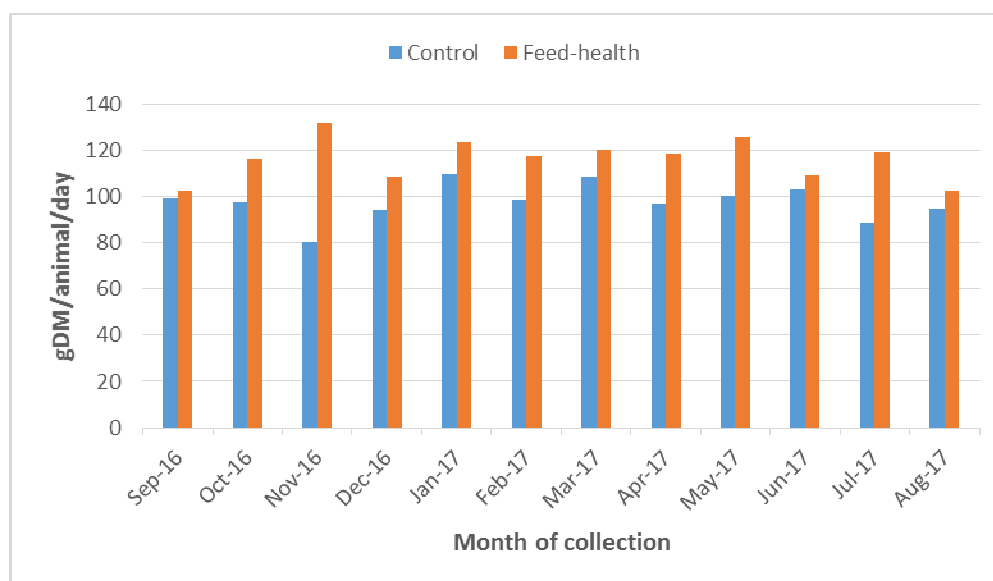


Figure 6: Manure collected per animal per day (g DM/animal/day) by farmers from sheep and goats under control and feed-health intervention groups



Picture 3: A farmer spreading manure collected from his flock on the crop field.

3.4. Nutritional quality of the available feed resources

Apart from the natural pastures, the other major feed resources found in the study sites were crop residues, agro-industrial by-products and browses. The common crop residues included sorghum stover, cotton straw, cowpea hay and groundnut haulms (Table 5) while the agro-industrial by-products were cotton seed cake and maize bran. Cotton seed cake had the highest crude protein among the feed resources offered to sheep and goats by the farmers in the two treatments. The legume residues (cowpea hay and groundnut haulm) were also high in crude protein and *in vitro* organic matter digestibility. The browses (leaves of shrubs and trees) are important feed resources in the late dry season when there is feed scarcity (Umutoni et al., 2015) and they generally have high crude protein content but they are high in lignin content (Table 5). The values of crude protein content of the cowpea hay and groundnut haulm in this study were higher than those reported by Umutoni et al. (2015) which could be attributed to period of collection of the feed samples and the associated differences in the leaf : stem ratio.

Table 5. Chemical Composition of the main feed resources for ruminants in Zanzoni and Sirakele, Koutiala district (% on a dry matter basis)

Feed type	OM	CP	NDF	ADF	ADL	IVOMD	ME(MJ/kg DM)
Crop residues							
Cowpea hay (leaves & stems)	88.46	19.06	36.06	24.57	5.65	72.03	9.83
Groundnut haulm (leaves & stems)	88.67	16.30	54.69	44.22	9.32	61.63	8.85
Cotton straw (leaves & stems)	95.74	13.01	47.42	20.79	6.09	71.21	9.47
Sorghum stover (leaves & stems)	94.41	4.23	71.59	46.29	6.38	51.91	7.68
Agro byproduct							
Cotton seed cake	89.33	25.15	65.28	43.54	8.35	71.04	9.73
Maize bran	94.13	16.15	42.19	10.08	1.97	74.64	10.44
Herbage							
<i>Cenchrus biflorus</i>	85.28	17.78	49.79	34.31	7.13	65.76	8.96
Browse							
<i>Vitellaria paradoxa</i> (leaves)	90.43	11.15	41.09	32.79	12.64	58.56	8.69
<i>Sclerocarya birrea</i> (leaves)	93.67	14.98	45.28	44.88	18.27	41.06	6.25
<i>Guiera senegalensis</i> (leaves)	96.69	10.97	49.11	43.43	14.89	55.77	8.62
<i>Ziziphus mauritiana</i> (leaves)	93.77	17.76	45.28	30.87	8.77	64.99	9.70
<i>Saba senegalensis</i> (leaves)	90.07	10.12	36.36	28.47	12.69	51.46	7.86

OM: Organic Matter; **CP:** Crude Protein; **NDF:** Neutral Detergent Fiber; **ADF:** Acid Detergent Fiber; **ADL:** Acid Detergent Lignin; **IVOMD:** In Vitro Organic Matter Digestibility; **ME:** Metabolizable Energy

The legume residues like cowpea hay and groundnut haulms are normally collected and stored, and used to feed household animals in the dry season or sometimes sold as the prices are often high (Ayantunde et al., 2014). The cereal straws are normally left on the crop field to be grazed by the animals. However, some farmers do collect and store them at homestead to feed the household's flock. The quantity and quality of feed resources available decreased as the dry season progressed. Also, the importance of crop residues decreased as the dry season progressed while that of browse increased. Fodder trees and shrubs play an important role in ruminant nutrition in the late dry season (March to May; Ickowicz and Mbaye 2001). The preference for browse species varied according to season and animal species. The goats tended to prefer browses compared to sheep; hence, browses form a significant proportion of goat diet during the late dry season (Zampaligré et al., 2013).

3.5. Partial cost and benefit analysis

The results of partial cost and benefit analysis of the control and feed-health intervention showed that the net return from the intervention was significantly higher than for the control (Table 6). The annual net return for the treatment was $107,260 \pm 25,388$ FCFA per household compared to $89,798 \pm 8,693$ FCFA per household. The sources of revenue were weight gained, manure collected and animal sale (offtake; Table 6) while the costs were associated with veterinary care and feed cost. The results showed that traditional small ruminant production with low inputs is profitable provided there is no major disease outbreak, which could explain the reason for widespread rearing of small ruminants by smallholder farmers. However, the farmers can generate more revenue through small ruminant production by providing supplementary feed and healthcare for their animals. For households with high flock size, it is prudent and profitable to provide supplementary feed and standard healthcare (vaccination against PPR and Pasteurellosis, deworming and curative measures) to their animals as the risk is high of losing most of the animals in the event of major disease outbreak like PPR with reported mortality rate of 80% (Ba et al., 1996). The annual profits reported in this study were lower than the annual profits obtained from one hundred dairy sheep of 362,700 FCFA and 476,400 F.CFA for one hundred dairy goats in a study by Nantoume et al. (2011) in Kaye region of Mali. If annual profits reported by Nantoume et al. (2011) were to be adjusted to the flock size in our

study, the annual profits in our study will be higher than the returns from dairy sheep and goats. Our results confirm that feed and health intervention to improve small ruminant production is profitable. Providing the enabling environment for veterinary services is critical to access the health services by the farmers for their animals.

Table 6. Partial cost and benefit analysis (FCFA/household/year) of control and feed health intervention of small ruminants in Zanzoni and Sirakele, Koutiala district for 1 year

Variable	Control (n=20)	Feed-health (n=20)
Revenue from weight gains	46,596±3,364 ^a	241,058±14,189 ^b
Revenue from manure collected	5,886±519 ^a	15,474±844 ^b
Revenue from animal sale	38,537±7,560 ^a	169,125±26,549 ^b
Gross return	91,020±8,738 ^a	425,657±34,961 ^b
Supplement (cotton seed cake) cost	0 ^a	300,988±17,717 ^b
Veterinary cost	2,445±176 ^a	29,320±1,725 ^b
Total cost	2,445±176 ^a	330,308±19,442 ^b
Net return	89,798±8,693 ^a	107,260±25,388 ^a

Cotton seed cake 150 FCFA per kg; PPR, Pasteurellosis and trypanosomiasis vaccinations– 175 FCFA per animal; treatments & deworming (200 FCFA per animal per quarter); manure 20 FCFA per kg air dried manure; weight gain - 750 FCFA/kg live weight.

Values for each variable with different superscript are statistically significant ($P<0.05$).

3.6. Feedback from the farmers about the pilot study

To assess the impression of the participating farmers of the pilot study in both study communities, a meeting was organized on 31 October, 2017 and 1 November, 2017 in Sirakele and Zanzoni, respectively. Farmers in Sirakele expressed their gratitude to the project for the pilot study through which their flocks were provided with cotton seed cake and healthcare. They were really happy for the positive effects of the feed and health intervention on the performance of their animals. They observed that after one year of the study they have seen tremendous improvement in body weight development of their animals and in their flock size. According to them, their flock size doubled or even tripled. They even said that the way their flock increased rapidly suggests that they can even depend on small ruminant rearing for livelihood. Specific benefits from the feed and health intervention according to the participating farmers in Sirakele included drastic reduction in mortality rate, increase in birth rate, additional household income through increased offtake, increased body weight, and high quantity of manure collected. In addition, their knowledge of management of small ruminants improved

through the training provided by the project. On the improved small ruminant husbandry, they acquired knowledge on animal healthcare, particularly awareness of the vaccination against different diseases and the importance of deworming, through the trainings provided. They also stated that they acquired knowledge on how to feed their sheep and goats to improve their body weight development. Furthermore, as result of the study, they realized that they could collect significant amount of manure from their animals and this has led them to take initiative to build pens or hangars for their animals. According to the farmers, many of them were not really interested in small ruminant rearing before as it was considered as activity for women but after one year of the study, they have realized the great potential small ruminant rearing can contribute to their family well-being. As a result of this, most of the farmers said that they will continue with the vaccination of their animals and with provision of supplementary feed.



Picture 4: Group discussion with participating farmers in Sirakele



Picture 5: Group discussion with participating farmers in Zanzoni

The farmers in the control group in Zanzoni were not enthusiastic about the project because there was no any intervention. The project gave a 50 kg bag of rice to each household towards the end of the study for their participation. The farmers reported high mortality rate in their flock and the constraint of feed availability, especially during the rainy season where they have to tether their animals and feed them at home, to avoid damage to their crops. However, the farmers said that the study raised their awareness on the potential of collecting large amount of manure from small ruminant rearing for the crop field. The daily collection of manure also made them to clean the animal pens and sheds. The feedback from farmers in both Sirakele and Zanzoni suggests that building their capacity in animal husbandry is essential to improving small ruminant production in mixed crop and livestock systems in Mali and in other Sahelian countries. Also building awareness of the benefits of small ruminant rearing can motivate the

farmers to invest in better management of their flocks. For example, construction of pen or hangar for housing the animals will facilitate collection of animal manure for application on the crop field. Extension services which are weak in Mali and in other countries in the region need to be strengthened to build the capacity of the farmers in improved animal husbandry.

4. Conclusion and Recommendations

This pilot study was conducted to assess the effects of combined feed and health interventions on small ruminant production in mixed crop and livestock systems in Zanzoni (control) and Sirakele (feed-health intervention) in Koutiala district in southern Mali. Based on the results of this study, the major conclusions are:

- i). Feed and health intervention leads to rapid flock growth of sheep and goats within a short period in a profitable manner, through significant increase in birth rate and reduction of mortality rate. This flock growth provides opportunity for increased offtake by the households.
- ii). Supplementary feeding in addition to basal feed and vaccination against major small ruminant diseases improves body weight development and increases the quantity of manure that can be collected for fertilizing the crop field.
- iii) Though traditional small ruminant production with low external inputs is profitable provided there is no major disease outbreak and good feed resource base as in southern Mali, additional income could be generated by the household by investing in supplementary feeding and healthcare of the flock.
- iv). The pilot study provides evidence that small ruminant husbandry can be profitable even with provision of supplementary feed and healthcare which led the household in Sirakele whose flocks benefited from feed and health intervention to make a strong commitment to continue with the intervention albeit in a modified version. The main challenge they may face is availability of the necessary veterinary services.

Some recommendations from the pilot study agencies are:

- i). Provision of a good housing or shed for the household flock is necessary for collection of appreciable quantity of manure for the crop field. To avoid contamination of the manure, the

animal house or shed should be kept clean. Daily cleaning of the animal house is also beneficial in terms of reducing favourable conditions for disease.

ii). Nitrogen in urine can be better capture by putting cereal straws on the floor of the animal house or shed as beddings. The beddings can then be used as mulch on the crop field.

iii). Access to veterinary services can be enhanced if the farmers can organize themselves and then approach the local government authority in their area to facilitate contact with the animal health workers/veterinarians. It may also be necessary to have a contract with the veterinary agents for the provision of services. Again this will require that the farmers are organized.

iv). Building the capacity of the farmers in improved animal husbandry is critical to the success of any community level livestock-related intervention. It is therefore important that necessary trainings are incorporated into any intervention plan.

v). Though cotton seed cake was used as feed supplement in this study due to availability in southern Mali, any protein rich crop residues such as cowpea hay, groundnut haulms or agro-industrial by-products such as maize bran, millet bran can be used.

vi). Group herding of the sheep and goat flock to the grazing areas is necessary during the cropping season to avoid damage to crops, and this is good from nutrition point of view than tethering the animals around the homestead without adequate provision of feed.

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